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(54) Abstract Title
Slot Allocation in a TDD Wireless Communication System

(57) A communication system (100) including a base station (101) and mobile units (103) uses pairs of time slots (207-221) for TDD communication with each remote unit. Slots are allocated according to a determined rate of change of a propagation characteristic of the communication link so that the time between the slots of a pair is reduced as the rate of change increases. Alternatively, time slot pairs are allocated so that the maximum time between the slots is reduced for increasing rates of change. By allocating slots in this way improved channel coherency is achieved between consecutive slots and communication in one direction may be optimised using information obtained from communication in the other direction.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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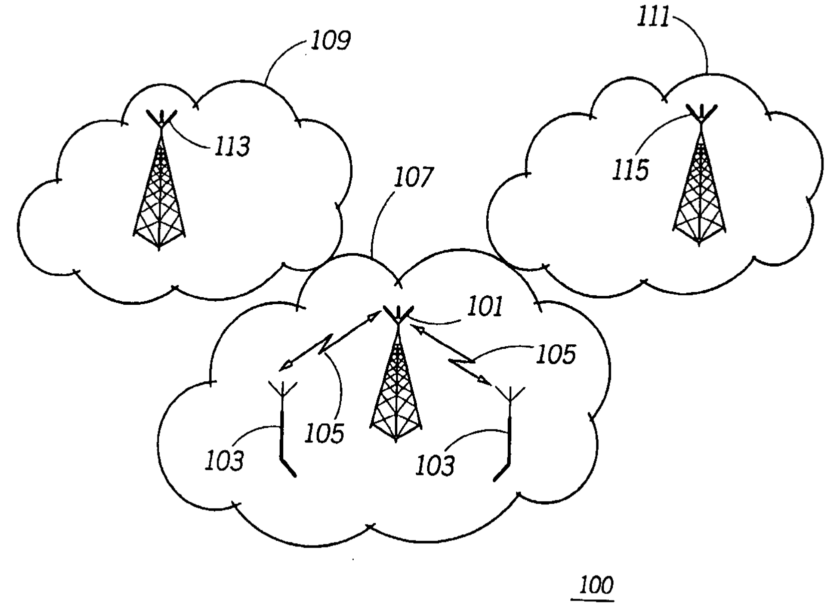

FIG. 1

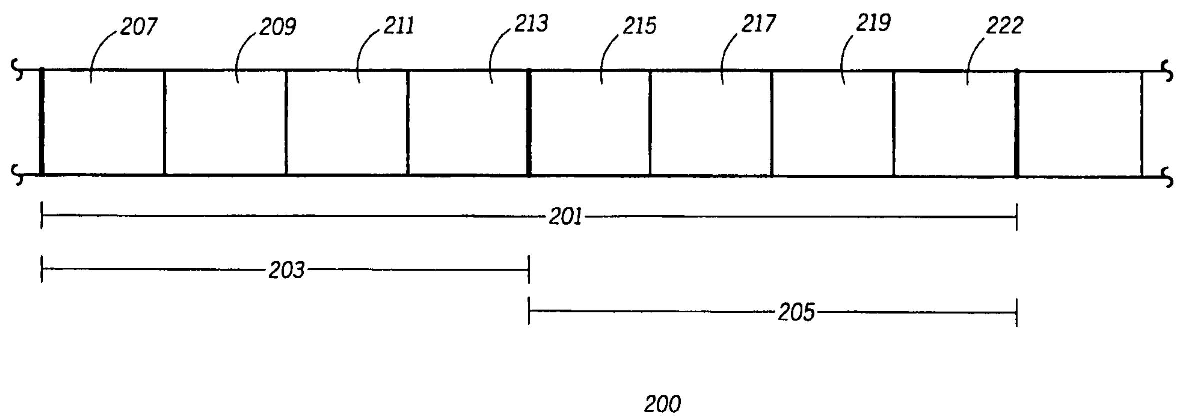

FIG. 2

COMMUNICATION SYSTEM AND RELATED METHOD

Field of the Invention

This invention relates to a communication system with at least one base station and at least one remote unit communicating using time slots.

Background of the Invention

Communication systems are known which use discrete time intervals for communication between a transmitter and a receiver. In many systems incorporating a base station communicating with a plurality of remote units the communication is divided between the remote units by allocating separate time slots for each remote unit.

An example of a communication system using this approach is the Global System for Mobile communication (GSM) which divide a time frame into 8 different time slots. Each remote unit is allocated one specific time slot for communication to the base station in this repeating time frame.

In the GSM system, one carrier frequency is allocated for communication from the base station to the remote unit (downlink) and another carrier frequency is allocated for communication from the remote unit to the base station (uplink). Other systems are known which use a method known as Time Division Duplex (TDD) in which the same carrier frequency is used for both uplink and downlink. The repeating time frame is in this case divided into an interval with time slots used in the uplink direction and another interval with time slots used in the downlink direction.

Some systems are known which utilise knowledge of the propagation characteristics of the communication link to adjust a characteristic of the transmission to achieve a more efficient use of the available resource. For example systems communicating over a wireline which modify the symbol constellation according to the quality of the link are known. Most of these systems use feedback of information on the state of the link. Some experimental systems are known which operate in a TDD mode and use an estimate of the link in one direction for adjusting a characteristic of the

transmission in the other direction. A requirement for this type of operation is that the rate of change of the communication link is sufficiently low for the estimate at the time of reception to be sufficiently accurate at the time of transmission.

Summary of the Invention

According to this invention a communication system is provided comprising a first base station communicating during a first and second time slot in a first time frame with a first remote unit over a first communication link, means for determining a first rate of change of a first propagation characteristic of said first communication link, and

means for allocating said at least first time slot in said first time frame based on said first rate of change.

The allocation of the first time slot may be so that a delay between said first and second time slot is decreased for increased values of said first rate of change or a maximum delay may be determined in response to said rate of change and said first time slot allocated so that a delay between said first and second time slot is less than said maximum delay.

According to an aspect of the invention the communication system may further comprise means for altering a transmission characteristic in a third time slot in response to a propagation characteristic of said first communication link in said first or second time slot.

Alternatively the communication system may further comprise a second remote unit communicating with said first base station during a third and fourth time slot in said time frame over a second communication link,

means for determining a second rate of change of a second propagation characteristic of said second communication link, and

means for allocating said at least first time slot in said time frame based on said first and second rate of change.

According to a different aspect of the invention there is provided a method of allocating time slots in a communication system with a first base station communicating during a first and second time slot in a first time frame with a first remote unit over a first communication link comprising the steps of: determining a first rate of change of a first propagation characteristic of said first communication link, and allocating said at least first time slot in said first time frame based on said first rate of change.

Brief Description of the Drawings

An embodiment of the invention is described below, by way of example only, with reference to the accompanying drawing.

FIG. 1 is an illustration of a communication system to which this invention is applicable.

FIG. 2 is an illustration of a time slot structure for a TDD communication system.

Detailed Description of a Preferred Embodiment

An example of a communication system which uses time slots for communication is the GSM communication system in which different carrier frequencies are allocated for uplink (transmission from remote unit to base station) and downlink (transmission from base station to remote unit). In each direction the carrier frequency is divided into time frames consisting of eight slots. Each of these slots can be assigned to a remote unit which will remain on the same time slot until ending the call.

An example of such a communication system 100 is illustrated in FIG. 1 where a base station 101 communicates with a number of remote units 103 over radio channels 105. Each remote unit and each central station contains a receiving unit and a transmitting unit. The communication system may be a cellular system where the central station covers users

within a certain geographical area 107 whereas other geographical areas 109,111 are covered by other central stations 113,115.

Systems with an option for using time slots for separating remote units while using the same carrier for both uplink and downlink have been proposed for the next generation European mobile communication system UMTS. This is known as Time Division Duplex (TDD) and an example of a time slot structure 200 suitable for TDD is illustrated in FIG. 2. A time frame 201 contains an downlink interval 203 and an uplink interval 205. The downlink interval contains time slots 207 - 213 used for transmission from the base station to the remote units and the uplink interval contains time slots 215 - 221 used for communication in the other direction. In the proposed systems for UMTS the time slots are intended to be paired so that time slot 207 and time slot 215 are used by the same remote unit, time slot 209 and time slot 217 by another remote unit and so on.

In accordance with the current invention a method is provided for allocating time slots in response to a rate of change of the communication link. By allocating time slots according to a rate of change of the communication link improved channel coherency can be achieved between consecutive time slots involving the same remote unit. This can be utilised to optimise the communication in one direction based on information derived from the received signal during communication in the other direction.

The description will consider the allocation of one uplink and one downlink time slot for each remote unit but this can be extended to more time slots as will be apparent to the person skilled in the art. Specifically, an asymmetric allocation where more time slots are allocated in one direction than in the other may be employed which will be beneficial for asymmetric traffic needs.

According to one aspect of the invention, the time slots are allocated in such a way that one of the delays between time slots for the same remote unit is reduced for increasing rate of change. If for example two remote units are communicating with the base station and one of the remote units

is a fast moving remote unit, while the other is moving very slowly, the rate of change for the first remote unit will be much higher than for the second. The communication link to the second remote unit might consequently remain constant for several time frames while the link to the first remote unit might only remain sufficiently constant over for example four time slots. According to the invention the time slots can in this situation be allocated so that the first remote unit is allocated time slots 213 and 215 while the second remote unit can be allocated time slot 207 and 221. In this way the channel during the uplink time slot 215 is nearly the same as the channel during the preceding downlink time slot 213. The remote unit can thus set a characteristic of the uplink transmission according to the estimate of the channel in the downlink time slot 213. However, as the difference between an uplink time slot 215 and a downlink time slot 213 is six time slots which is higher than the channel coherency duration of four time slots, the base station cannot base its downlink transmission on the channel estimated during the uplink time slot 215. In this case the adaptation to the channel conditions of the previous time slot can only be utilised in one direction.

If a third remote unit with similar characteristics as the first remote unit set up a call on the system, it could be allocated time slots 211 and 217. Alternatively the first remote unit could be reallocated the time slot 213 and 217, and the third remote unit could be allocated the time slot 211 and 215. With this allocation it is again ensured that the maximum delay from the downlink time slot to the uplink time slot is less than two time slots for the fast moving remote units thereby ensuring that the link is sufficiently constant. The fast moving remote units will consequently be able to for example modify characteristics of the transmission in the uplink time slot based on the received signal in the downlink time slot. As the link between the base station and the slow moving remote unit is relatively constant over the entire time frame, this remote unit can use the same technique although the delay between the time slots is much higher.

There can in some situations be practical considerations which impose restrictions on the allocation of time slots. If for example the remote units require a guard band between the uplink and downlink time slots of at

least one time slot in order to switch from one mode to the other, the time slot allocation in the previous case with two remote units can result in the first remote unit being allocated slot 213 and 217 and the second remote unit being allocated the time slots 209 and 221.

By allocating the time slots so that one of the delays between time slots of the same remote unit is reduced for increasing rates of change, the channel coherency between the receiving and the transmitting time slot for either the remote unit or the base station can be increased. This will allow either the remote unit or the base station to improve the transmission based on a characteristic measured in the receiving time slot. However, increasing the channel coherency for the remote unit will decrease it for the base station and vice versa. According to a different aspect of the invention, the time slot allocation may be such that the maximum delay between the two time slots for the same remote unit is reduced for increasing rates of change. For example, a fast moving remote unit with associated high rate of change will be allocated the time slots 209 and 217 while a slow moving remote unit will be allocated any set of time slots for example time slot 213 and 215. The maximum delay between two time slots for the fast moving remote unit is thus 3 time slots whereas it is 6 time slots for the slow moving remote unit. In this case the fast moving remote unit will be able to utilise the channel coherency in both the uplink and downlink direction which would not have been possible if it had been given an allocation optimising just one of the delays.

Combinations of the above described allocations may be applied. For example, remote units can be divided into remote units with a rate of change which is so high that sufficient channel coherency cannot possibly be achieved in both directions, remote units with an associated rate of change so low that sufficient channel coherency can be achieved in both directions for some time slot allocations, and finally very slow moving remote units with channel coherency extending over one time frame. In this scenario, the first set of remote units would preferably be allocated according to the first described alternative, the second set of remote units according to the second alternative and the third set of remote units can be allocated freely in the remaining time slots. When channel coherency can

only be used in one direction, it is preferred that this is done in the central station thereby improving the downlink, which typically represents the worst case in a cellular communication system.

A maximum allowable delay between time slots can be determined from the rate of change of the communication link. This maximum delay would be determined so that the channel coherency would be sufficiently high for the desired operation to be performed. For example, if the desired operation is to base the uplink signal power on the downlink received signal level, a certain rate of change may correspond to a channel coherency which makes this feasible as long as the delay between the time slots is less than two time slots. This can result from the receiver having measured the received signal level for a certain duration of time and identified that fluctuations in signal levels and thus fades of the channel are so slow that they can be considered constant within a certain limit for a duration of four time slots. The allocation of time slots can hence be performed freely under the constraint of the delay between two time slots being less than two time slot intervals.

If the requirements of the remote units having time slots allocated are such that the constraints can not be met for all remote units, the time allocation will preferably be so that the constraints of the highest number of remote units are met. The remaining remote units will be allocated time slots which still allow communication but without the option of using the desired operation. Remote units allocated slots suitable for the desired operation are with this approach guaranteed a channel coherency below a certain threshold and can therefore apply the operation without any requirement for evaluating the actual channel coherency.

Alternatively the remote units can simply be ordered so that the higher the rate of change the closer the time slots are together. For example, if a first remote unit has an associated rate of change which is higher than that associated with a second remote unit, it will be allocated time slots between the time slots of the first remote unit. The first remote unit can according to this alternative be allocated time slot 211 and 217 while the second remote unit will be allocated time slot 213 and 215. A third remote unit with

an associated rate of change between the first two would cause the first remote unit to be reallocated to time slots 209 and 219, and would itself be allocated time slots 211 and 217. In this approach the channel coherency between time slots for the same remote unit will change dynamically and will be dependent on which other remote units are active. The desired operation for utilising the channel coherency will therefore preferably be able to alter the operation depending on the actual coherency.

Any combination of the above two alternatives can be applied. For example, the time slots can be allocated according to the first alternative but with the allocation within the delay constraints being such that the remote units with faster rate of change are allocated time slots between the remote units with slower rate of change when possible.

The allocation of time slots in response to one or more rates of change can apply to one or more of the time slots, but preferably all time slots will be allocated in response to the determined rates of change. The allocation can be based on one or more of the communication links but preferably all communication links will be considered in the allocation.

According to the invention, the allocation of time slots based on a rate of change of the communication link will also apply to a situation where there is a plurality of carrier frequencies each with time frames in which slots can be allocated.

The method for allocation of the time slots can be implemented in a controller which preferably will consists in a software program in a suitable computational device. Methods for implementing a controller is well known in the art and will be apparent to the skilled reader.

Preferably the system will also include a controller for determining the rate of change of the communication link based on a characteristic of the received signal. This information will be provided to the controller for allocation of the time slots. One option is for the controller to generate a channel estimate in each time slot and correlate the estimates of the subsequent time slots. The rate at which the decorrelation increases is

indicative of the rate of change of the communication link. Another option is for the controller to measure the rate of received power level fluctuations within and between time slots. Again the speed of the fluctuations are indicative of the rate of change of the communication link. Alternatively the rate of change of the link can be determined from directly measuring the speed of the remote unit as the rate of change typically increases for faster moving remote units. In this way a short delay between time slots would be allocated when the remote unit is moving whereas no requirements would be imposed when the remote unit was stationary. This option is specifically be suited for applications where a remote unit is integrated with a vehicle. The person skilled in the art may substitute any known method for determining a rate of change of a communication link without subtracting from the current invention. The controller can be situated in the base station 101, the remote unit 103 or can be distributed in the system.

The allocation of time slots is preferably communicated between the base station and the remote units using a predefined protocol. An approach similar to GSM where time slot allocation is communicated from the base station to the remote units at call setup and during handover from one cell to another can be implemented. However, it is the preferred embodiment that a dynamic update of the time slot allocation is employed where the base station frequently communicates the time slot allocation to the remote units. Preferably the time slot allocation of the next time frame will be communicated during the current time frame thereby allowing a new time slot allocation for each new time frame. The communication of the time slot allocation for a given remote unit can simply be included in a few specified bits within the time slot for the given remote unit. Alternatively, the information can be communicated on specific control channels which can be common for all remote units. An example is a cellular system employing a dedicated control carrier, such as the BCCH carrier in the GSM system, where the time slot allocation can be frequently included.

The invention provides a method and apparatus for allocating time slots so that the channel coherency between time slots allocated to the same remote unit is increased for fast moving remote units while remaining sufficiently

high for slower moving remote units. This provides a substantial advantage as it substantially increases the possibility of using channel adaptation. Systems which adaptively alter a transmission parameter dependent on the current channel conditions have been shown to yield substantially increased data throughput. An example, is a system which increases the number of constellation points as the channel quality improves. These systems typically use a method of feed back of channel information to set the transmission parameter but a feed forward method wherein the transmission parameter is set dependent on a received parameter are feasible. An example is a system which assumes that if a high signal level is received from the base station, then the path loss of the reverse path will also be low, and it therefore increases the number of constellation points accordingly. A requirement for these systems to work is that the channel coherency between the receiving time slots and the transmitting time slots is sufficiently high. The current invention therefore provides a significant benefit for these systems.

Claims

1. A communication system comprising a first base station communicating during a first and second time slot in a first time frame with a first remote unit over a first communication link,

a first processor for determining a first rate of change of a first propagation characteristic of said first communication link, and

a first controller for allocating at least said first time slot in said first time frame based on said first rate of change.

2. A communication system as claimed in claim 1 wherein at least said first time slot is allocated within said first time frame so that a delay between said first and second time slot is decreased for increased values of said first rate of change.

3. A communication system as claimed in claim 1, wherein a maximum delay is determined in response to said first rate of change and said first time slot is allocated within said first time frame so that a delay between said first and second time slot is less than said maximum delay.

4. A communication system as claimed in claim 1 wherein at least said first time slot is allocated within said first time frame so that a longest delay of a first delay from said first time slot to said second time slot and a second delay from said second time slot to said first time slot is decreased for increased values of said first rate of change.

5. A communication system as claimed in claim 1, wherein a maximum delay is determined in response to said first rate of change and said first time slot is allocated within said first time frame so that a longest delay of a first delay from said first time slot to said second time slot and a second delay from said second time slot to said first time slot is less than said maximum delay.

6. A communication system as claimed in any of the preceding claims 1 to 5 further comprising:

a second controller for altering a transmission characteristic in a third time slot in response to a propagation characteristic of said first communication link in said first or second time slot.

7. A communication system as claimed in claim 1 wherein said first rate of change is estimated from an indicator chosen from the group of

a) remote unit speed
b) correlation of channel estimates
c) received signal level.

8. A communication system as claimed in claim 1 wherein an allocation of time slots is communicated from said first base station to said first remote unit.

9. A communication system as claimed in claim 8 wherein said allocation of time slots applicable to said first time frame is communicated in a second time frame prior to said first time frame.

10. A communication system as claimed in Claim 1 further comprising a second remote unit communicating with said first base station during a third and fourth time slot in said first time frame over a second communication link,

a second processor for determining a second rate of change of a second propagation characteristic of said second communication link, and

a second controller for allocating said at least first time slot in said first time frame based on said first and second rate of change.

11. A communication system as claimed in claim 10 wherein said at least first time slot is allocated within said first time frame so that a first delay between said first and second time slot is lower than a second delay between said third and fourth time slot when said first rate of change is higher than said second rate of change.

12. A communication system as claimed in claim 10, wherein a first maximum delay is determined in response to said first rate of change, a second maximum delay is determined in response to said second rate of

change and said at least first time slot is allocated within said first time frame so that a first delay between said first and second time slot is less than said first maximum delay, and second delay between said third and fourth time slot is less than said second maximum delay.

13. A communication system as claimed in any of the claims 10 to 12 further comprising

a third controller for altering a transmission characteristic in a fifth time slot in response to a propagation characteristic of said first communication link in said first or second time slot.

14. A method of allocating time slots in a communication system with a first base station communicating during a first and second time slot in a first time frame with a first remote unit over a first communication link comprising the steps of:

determining a first rate of change of a first propagation characteristic of said first communication link, and

allocating said at least first time slot in said first time frame based on said first rate of change.

15. A method as claimed in claim 14 wherein at least said first time slot is allocated within said first time frame so that a delay between said first and second time slot is decreased for increased values of said first rate of change.

16. A method as claimed in claim 14 further comprising the steps of:

determining a maximum delay in response to said first rate of change; and

allocating said first time slot within said first time frame so that a delay between said first and second time slot is less than said maximum delay.

17. A method as claimed in claim 14 wherein at least said first time slot is allocated within said first time frame so that a longest delay of a first delay from said first time slot to said second time slot and a second delay

from said second time slot to said first time slot is decreased for increased values of said first rate of change.

18. A method as claimed in claim 14 further comprising the steps of:

determining a maximum delay in response to said first rate of change; and

allocating said first time slot within said first time frame so that a longest delay of a first delay from said first time slot to said second time slot and a second delay from said second time slot to said first time slot is less than said maximum delay.

19. A method as claimed in any of the preceding claims 14 to 18 further comprising the step of:

altering a transmission characteristic in a third time slot in response to a propagation characteristic of said first communication link in said first or second time slot.

20. A method as claimed in claim 14 wherein said first rate of change is estimated from an indicator chosen from the group of:

a) remote unit speed
b) correlation of channel estimates
c) received signal level.

21. A method as claimed in claim 14 further comprising the step of:

communicating an allocation of time slots from said first base station to said first remote unit.

22. A method as claimed in Claim 14 with a second remote unit communicating with said first base station during a third and fourth time slot in said first time frame over a second communication link and further comprising the steps of:

determining a second rate of change of a second propagation characteristic of said second communication link, and

allocating said at least first time slot in said first time frame based on said first and second rate of change.

23. A communication system substantially as hereinbefore described with reference to the accompanying drawing.

24. A method for allocation of time slots substantially hereinbefore described with reference to the accompanying drawing.

The Patent Office

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Claims searched:	all	**Date of search:**	20 May 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4L (LDSW, LDSU)

Int Cl (Ed.6): H04B 7/26; H04Q 7/38

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB2293947 A1 (TOSHIBA)	
A	WO97/13388 A1 (ERICSSON)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		